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A study of the pelagic gastropods of the Dillon Beach area pteropods and heteropods

Joan Laverne Gerdts
University of the Pacific

A STUDY OF THE PELAGIC GASTROPODS OF THE DILLON BEACH AREA PTEROPODS AND HETEROPODS

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by

Joan Laverne Gerdts

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Joan Laverne Gerdts,

is approved for recommendation to the

Graduate Council.

Department Chairman or Dean:

_____

Thesis Committee:

Joel W Hedgpeth, Chairman

John S. Tucker

Gilbert C. Hughes III

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

INTRODUCTION

In August 1959 Pacific Marine Station (P.M.S.) located at Dillon Beach, began a program of oceanographic study as a member of the California Co-operative Oceanic Fisheries Investigations (C.C.O.F.I.). The program continued through the summer of 1963 and consisted of a monthly hydrographic station and sampling the plankton at the head of Bodega Submarine Canyon, located twenty-five miles west of Bodega Bay. Two plankton tows were taken on each ocean run. One of the samples, along with collection and hydrographic data, was sent to Scripps Institute of Oceanography. The other sample was retained at P.M.S. and constitutes the material for the present study.

Pelagic gastropods were present in every tow in varying numbers and species. Two groups, pteropods and heteropods, were found in the samples. One species of pteropod, Limacina helicina, was the dominant member in all of the tows and occurred during the entire year. Little work has been done on the pelagic gastropods of the North Pacific. The information available has been mainly compiled by Tesch in the Dana Reports and McGowan (1960). Taxonomically the group has been extensively studied, but little is known about the life cycles, size ranges, growth rates, physiology, behavior, distribution and abundance.

No previous study on the pelagic gastropods collected by P.M.S. has been made. This paper is a discussion of the pelagic gastropods collected over a period of four years. It is the purpose of this study to identify, examine, and present information on the local specimens collected by Pacific Marine Station.

METHODS AND MATERIALS

Pacific Marine Station plankton tows were taken from August 1959 through August 1963. They were conducted by graduate students in residence at P.M.S. on a chartered fishing boat from Bodega Bay under the C.C.O.F.I. program. Tows were taken at the head of Bodega Submarine Canyon approximately twenty-five miles off shore. Two points in the area served as centers of collection. The Station I area, located at approximately 38°14'N, 123°26'W, served as the main collection center during the four years of the program. This station was located over the head of the submarine canyon in 535 meters of water. The Station II area at 38°16'N, 123°12'W was located to the east of the first area and closer to shore. It was the site of some additional plankton tows taken for P.M.S. in 1961. The water in the Station II area is 91 meters deep. (Figure 1.)

Fifty-six tows taken for P.M.S. were used in the present study. (Table XII) These tows were taken approximately once a month with more frequent sampling during the summer of 1961. During the course of the cruise, drift bottles were released and a bathythermograph record and hydrocast were made in addition to the plankton tows. Qualitative oblique tows were made which collected from the surface to the assumed maximum depth, which was

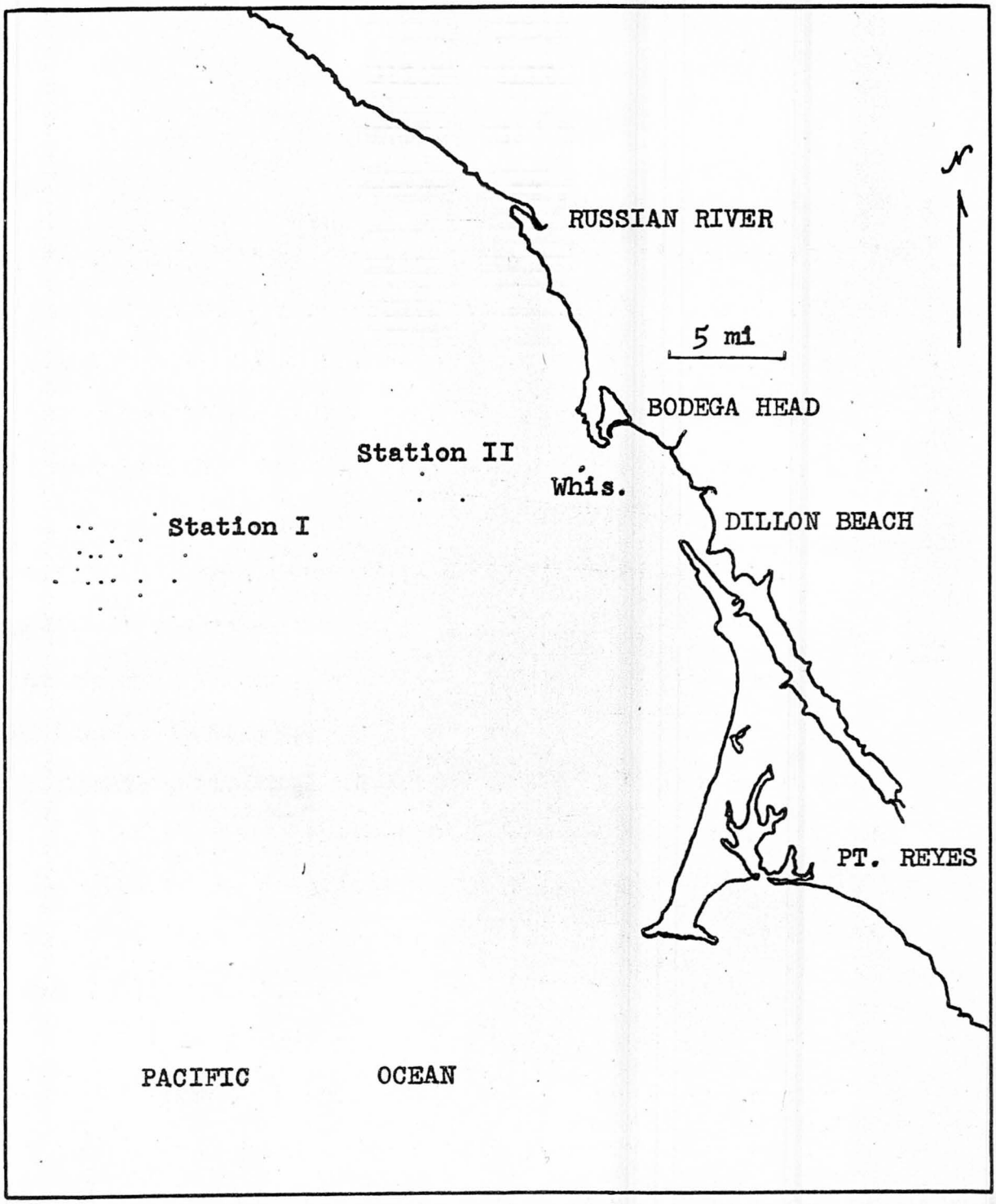


FIGURE 1: The Pacific Marine Station collection area showing Station I and Station II and the points of collection.

calculated by multiplying the cosine of the wire angle times the meters of wire out. The plankton net used was a half-meter net with #5 bolting silk. The samples were put in 32 oz. specimen bottles, labeled and preserved with 5% formaldehyde aboard the ship prior to its return to P.M.S.

The plankton samples were stored at P.M.S. and examined at a later period. It was found that occasionally the formaldehyde had dissolved the shells of the pelagic gastropods. In one sample the shells were completely dissolved after four months. In order to study these animals with the shell intact they should be preserved in alcohol or transferred to alcohol as soon as possible. At the start of this study, all of the animals taken in the P.M.S. plankton tows were sorted and the pelagic gastropods were set aside in separate bottles. The specimens were measured with a dissection scope and a calibrated ocular micrometer and the sizes recorded. An attempt was made to examine the reproductive tissue of the animals collected. Morton (1954) reported staining whole specimens of Limacina with Ehrlich's haematoxylin which the present author found to be totally unsuccessful. The most successful procedure found was to remove a small piece of desired tissue and stain it for one minute with acid

carmine. The acid carmine stain was made by dissolving carmine in boiling 45% acetic acid.

The author was fortunate to have the chance to study aboard the R/V TE VEGA during the summer of 1963 and to observe the pelagic gastropods while still alive. It was possible to become familiar with many of the different forms and examine them when they were first caught.

HYDROGRAPHIC CONDITIONS

The P.M.S. collection area is located in the California Current System, which is part of the Transition Water Mass in the North Pacific. This is a region of the extensive mixing of the Subarctic Water Mass to the north and the Eastern North Pacific Central Water Mass to the west. (Figure 2.)

The California Current is a complex current system existing in the upper 200 meters of the nearshore waters along the coast. Skogsberg (1936) showed three distinct periods or seasonal cycles to exist in the California Current. The Oceanic Period in the fall carries subarctic water south along the coast. The Counter Current Period, existing from late fall or early winter until early spring, is a period of northward flowing currents along the coast. The Upwelling Period occurs through the summer and brings cold water along the shore from the deeper waters off shore.

In 1959, when P.M.S. joined the C.C.O.F.I. program, drift bottles were released during the monthly tow. Schwartzlose (1962) has reported the data compiled from these and similar releases. He found the California Current to flow southward the year round except along its eastern border. The nearshore water within 20-40 miles of the shore shows the three periods mentioned above. Schwartzlose

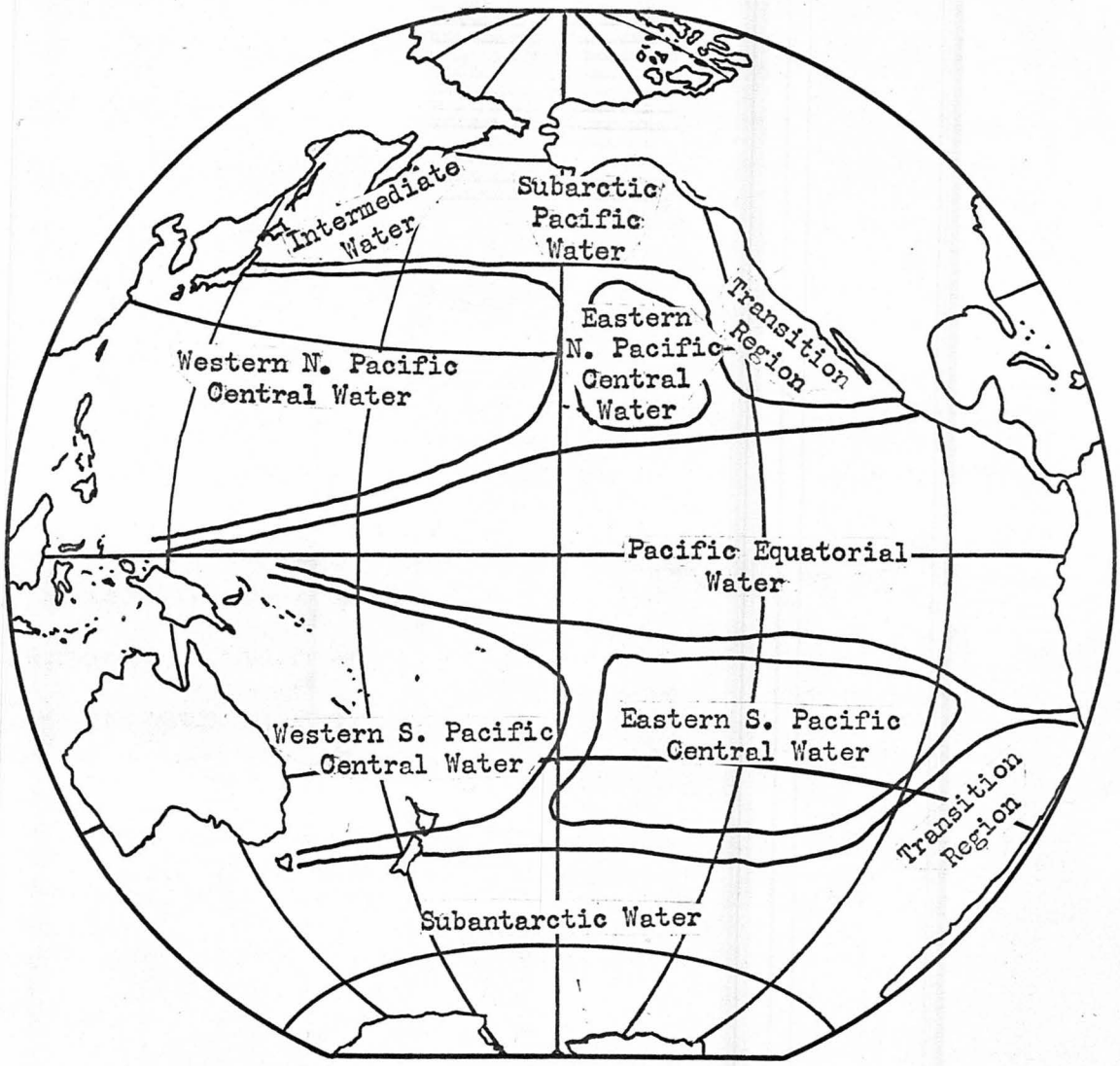


FIGURE 2: Water masses of the Pacific.
After Sverdrup (1946).

shows the Counter Current to develop along the Washington and Oregon coast in August or September and then to widen and move southward. In spring the process is reversed and the Counter Current recedes.

TAXONOMY

Taxonomically, the pelagic gastropods studied in this report are a diverse group. They have little in common other than their pelagic existence and the fact that they are protandrous hermaphrodites. They belong to two major gastropod groups. The opisthobranch gastropods are represented by the pteropods, and the prosobranch gastropods are represented by the heteropods. Major systematic and anatomical studies of pelagic gastropods were done as early as the late 1700's and early 1800's. A profusion of species were described and a vast number of synonyms now exist. The most comprehensive work on pelagic gastropods was presented by Tesch (1946, 1948, 1949, 1950) who has done much to clarify the taxonomy. Tesch compiled some of the first distributional data of this planktonic group. McGowan (1960) extended the study and worked on the Euthecosomes of the North Pacific, an area still needing extensive study.

Boas in 1886 and Pelseneer in 1888 were among the first to present the present concept of the pteropods (Tesch, 1946, 1948; Morton, 1954; McGowan, 1960). They contended that the pteropoda were not a natural group and created two separate orders of opisthobranchs: the Order Thecosomata and the Order Gymnosomata. Meisenheimer (McGowan, 1960) later created the two suborders of Thecosomata, the Euthecosomes and Pseudothecosomes. It

is this more natural system, summarized below and showing the local representatives which the present report follows

Class Gastropoda

Subclass Opisthobranchia

Order Thecosomata

Suborder Euthecosomata

Family Limacinidae: 2 mm.-1 cm., transparent, calcerous shell coiled to the left, ciliary mucous feeders.
Limacina helicina
Limacina inflata

Family Cavoliniidae: 5 mm.-18 mm., shell straight or cone shape, may be flexed or curved dorsally.
Clio pyramidata
Clio balantium
Cavolinia gibbosa

Suborder Pseudothecosomata

Family Cymbuliidae: large internal pseudoconcha, ciliary mucous feeders.
Corolla

Order Gymnosomata

Family Clionidae: no shell or mantle, head distinct, hook sacs, carnivorous.
Clione limacina

Subclass Prosobranchia

Superfamily Heteropoda

Family Atlantidae: 3 mm.-1 cm., shell transparent, coiled to right, flattened, with keel, eyes prominent, carnivorous.
Atlanta peroni
Atlanta lesueuri

Family Caranariidae: up to 20 cm., larval shell coiled, adult shell straight with keel, carniverous.
Caranaria lamarcki
Caranaria cristata

SYSTEMATIC ACCOUNT

Limacina helicina (Phipps)
PLATE I

This species was observed as early as 1675 by Friderich Martens (Tesch, 1946). It has been well examined in the Atlantic and other areas, but in the North Pacific it has been less extensively studied. Phipps called this species *Clio helicina*, but changed the genus to the present *Limacina helicina* (Tesch, 1948). McGowan (1960, 1963) very thoroughly reviews and describes this species and its varieties. During the course of the present study, *L. helicina* was by far the most abundant species collected. There were 1,631 specimens taken, representing approximately 93% of the total number of animals caught. *L. helicina* was collected at all but three of the 56 stations and was present during the entire year. The largest catch in a single tow consisted of 275 individuals. (Table XII.)

Most of the taxonomic characteristics of this group are based upon the shell. Unfortunately the shells are extremely fragile and are easily damaged in the tow or dissolved by the preserving fluid. The *L. helicina* shell is flattened and the inner whorls are mostly concealed in profile view. The shell is quite glassy. When empty and viewed with backlighting, the internal structure of the shell can be seen. (Plate Id.) Faint transverse striae

can be observed on some of the shells. An operculum is present in young individuals and is normally shed as the animal grows. (Tesch, 1946.) The operculum was not observed by Tesch nor by the author although some very small (0.3 mm.) specimens were collected.

The diameter of 1,553 individuals was measured by using a calibrated ocular micrometer and measuring the greatest diameter across the largest whorl of the shell. The range in size of the total population collected was 0.3 mm. to 3.9 mm. The largest of these (3.2-3.9 mm.) may be exaggerated and larger in size than is normal, due to the loss of the shell and uncoiling of the animal. The largest animals mentioned by McGowan (1960) were 2.4 mm. The mean size of the population was 1.1 mm. and the mode was 0.9 mm. in diameter. (Figure 3.)

Earlier observers noted a form of L. helicina which showed reduction of the striation on the shell. This form was named L. pacifica by Dall and L. rangi by d'Orbigny, who studied a form living in the transitional waters of the Antarctic. McGowan (1960, 1963) studied the L. helicina population of the North Pacific and shows two varieties to exist. One he designates as variety A, a higher spired form showing growth striae and having a height/diameter ratio of 1.20-0.85. In variety B the spire is flattened, the striation is lacking and the

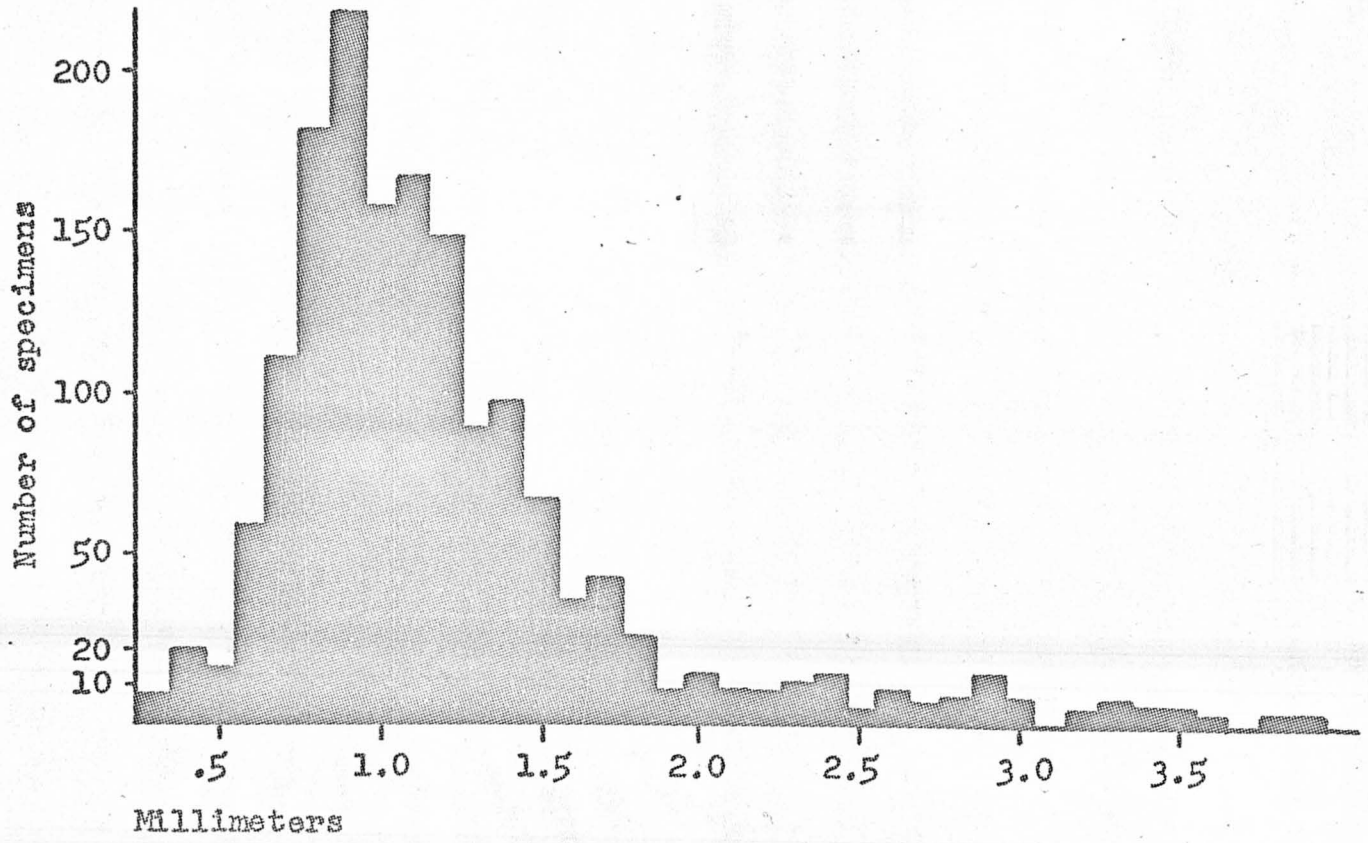


FIGURE 3: A size distribution of the Limacina helicina specimens taken in the Pacific Marine Station tows.

height/diameter ratio is 0.65-0.825. McGowan (1960) identified the North Pacific population in the area of this study as variety B. Some P.M.S. specimens measured had H/D ratios of 0.690-0.760. They had little or no vertical striation and fit McGowan's (1960) definition of variety B.

L. helicina occurs in the Subarctic Water Mass, the California Current and Gulf of Alaska waters. The two varieties have distinct North Pacific ranges within the overall species range (McGowan, 1960, 1963). Variety A occurs in the northern part of the Subarctic waters and variety B, caught in the P.M.S. tows, occurs in the Subarctic Transition waters east of 160°W between about 40°N and 45°N in the California Current and Gulf of Alaska waters. In this area there is a mass transport of water from west to east and McGowan (1960, 1963) concludes that the variety B population is derived from the variety A population.

Very little can be said about the vertical distribution of the P.M.S. specimens of L. helicina from the information available. During 1961 some tows were taken which had two nets fishing simultaneously. These are designated by the station number plus "T" for the net fishing on the top and a "B" for the net fishing on the bottom. (Table XII.) The mean size of the population

caught in the top (T) nets (<212 meters) was 1.9 mm. and for the bottom (B) nets was 1.3 mm. According to these results the larger animals were caught near the surface, which disagrees with Raymont (1963) who states that the younger animals are caught nearer the surface. Definite conclusions can not be drawn from this data because oblique tows were used. A more detailed study needs to be made, collecting specimens with opening and closing nets. The top net collected in an area almost equal to the entire vertical range of the species. McGowan (1960) shows that both variety A and variety B occurred in the upper 180-200 meters of water.

The mean size of the specimens taken in the P.M.S. tows was 1.1 mm. The monthly means were plotted by year. (Figure 4.) The mean size of the 1961 population was generally larger than that of the other three years. A complete explanation for this size increase is not possible from the data available. The population was much more intensively sampled in 1961 and some tows had both a top and bottom net attached. As mentioned above, the mean size of the animals taken in the top net was 1.9 mm. This was 0.8 mm. larger than the mean size of the total population. The largest change in the mean size in any one year (excluding means shown which indicate only one or a few specimens) was 0.5 mm. February and March show slightly

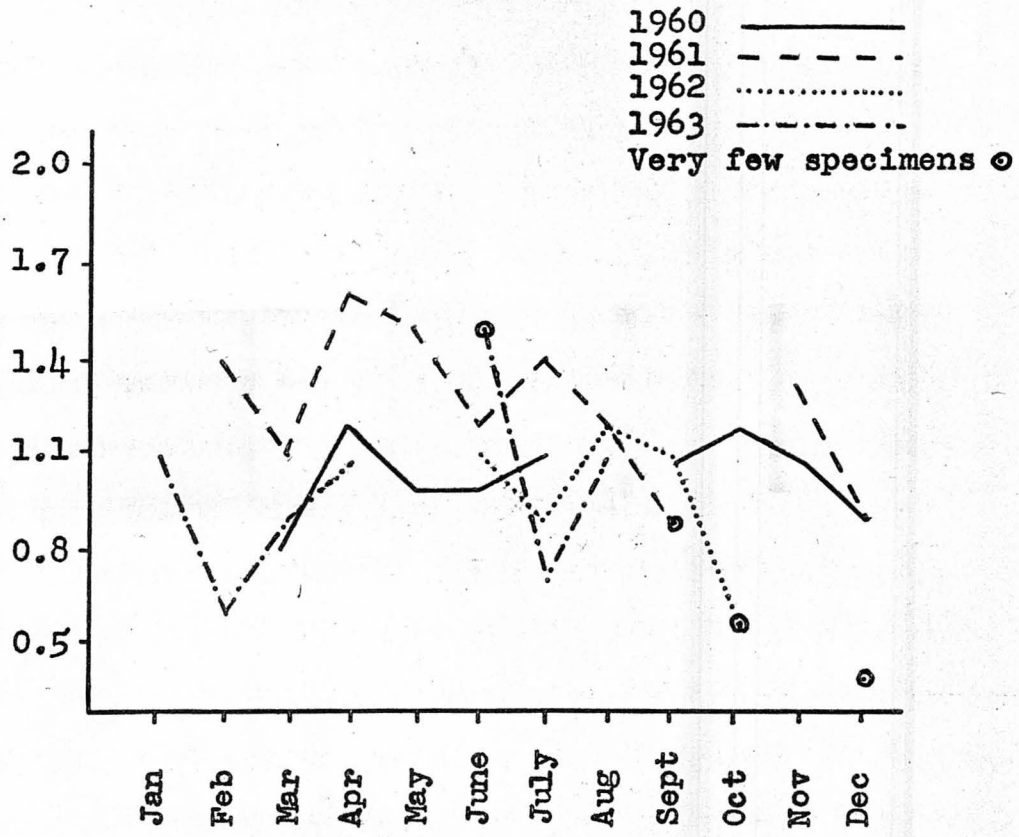


FIGURE 4: Limacina helicina population 1960-1963 Monthly mean size.

lower means, with a high mean in April. There was no consistent increase in size to indicate periods of growth during the year. The mean size of the local population fluctuates very little. Hsiao (1939b) and Redfield (1939) found that the L. retroversa population in the Gulf of Maine showed definite periods of growth amounting to 0.6 mm. or more in two months. This is more change than the local population shows in a year.

On twenty of the tows a flow meter was attached to the net and the volume of water filtered was recorded in cubic meters. These tows filtered a volume of water ranging from 48 to 379 meters^3. (Table XII.) This figure could then be used to find the number of specimens/1000 m^3. The number of specimens/1000 m^3 ranged from 0 to 1,280. The major portion of these fall within the 50-500/1000 m^3 reported for the area by McGowan (1960). Figure 5 shows this data plotted for each of the four years and the combined monthly average of the years. Two main peaks of seasonal increase are evident. They are in the winter and spring and correspond with the usual seasonal population increases of the period (Raymont, 1963). The first increase is in May during the Upwelling Period and the second is November to January during the Counter Current Period.

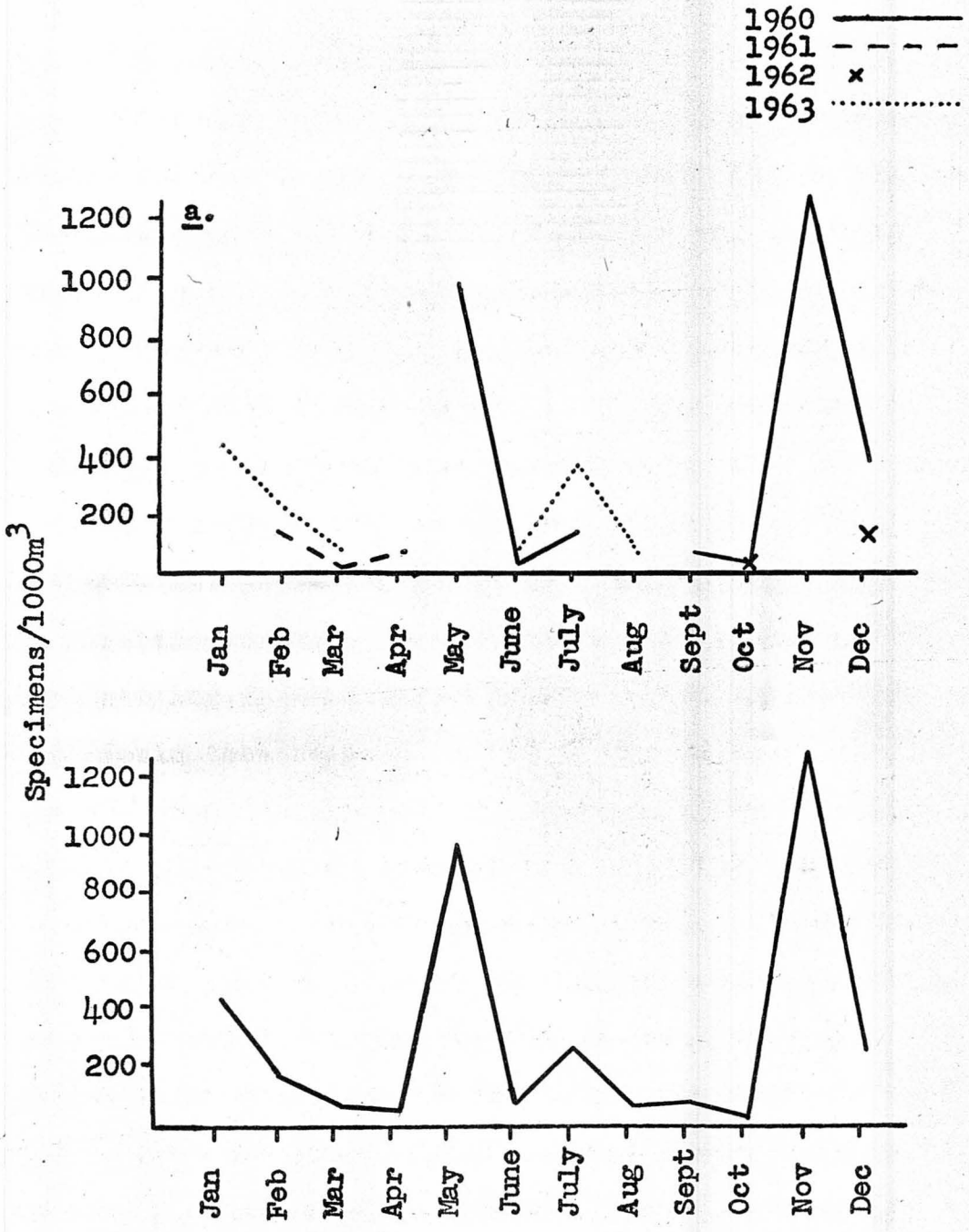


FIGURE 5: Number of Limacina helicina specimens/1000m^3.
a. Number of specimens/month 1960-1963.
b. Monthly average 1960-1963.

The reproduction of two closely related species has been studied. Hsiao (1939 a, b) studied L. retroversa in the Gulf of Maine, and Morton (1954) studied L. bulmoides in the Benguela Current. There are no comparable studies on the reproduction of L. helicina. The author selected four individuals from different size groups and dissected some tissue from the ovitestis. The ovitestis in Limacina lies posterior to the liver and occupies the last 3-4 whorls of the shell. Tissue from the anterior part of the ovitestis was stained with acid carmine and examined under a compound microscope. The smallest specimen examined (0.4 mm.) showed some undifferentiated tissue and some male tissue with immature, non-functional sperm. A specimen 1.1 mm. had almost completely differentiated male tissue. It was still a non-functional male with immature sperm. The third individual (2.3 mm.) was a functional male with mature sperm. About 50% of the ovitestis tissue was male and 50% female. There were a few mature ova but most were immature. The largest specimen examined was 3.3 mm. Again the tissue was about 50% male and 50% female, containing mature sperm and ova. This suggests that L. helicina is a protandrous hermaphrodite similar to the two closely related species, L. retroversa and L. bulmoides. Hsaio (1939 a, b) found the same stages in

L. retroversa.

TABLE I

Limacina retroversa (Hsiao, 1939 b)		Limacina helicina	
0.6-0.8	sexual differentiation	0.4	undifferentiated tissue male-immature sperm
1.0	100% male	1.1	100% male; non-functional, immature sperm
2.0	hermaphroditic male 50% male	2.3	50% male-functional, mature sperm 50% female-few mature ova
2.0	50% male 50% female	3.3	50% male-mature sperm 50% female-mature ova

Morton (1954) on L. bulmoides observed, in addition to the above stages, some completely female individuals. These were large specimens with mature ova but no sperm. This stage was not observed in even the largest of the P.M.S. specimens. Correlating the mean size of the P.M.S. population (1.1 mm.) with the information on the reproductive system on L. helicina, the local population is predominately males, mature or nearly mature, on the verge of developing female tissue.

A summary of the available data shows the local Limacina helicina population sampled by P.M.S. to be variety B of a fairly constant size which is being continually replenished from a parent population in the

Subarctic Transitional waters. Redfield (1939) showed the L. retroversa population in the Gulf of Maine to be replenished from the parent population off shore. He followed this population as it was carried along the Gulf by the currents and recorded its growth. The same should be done with the local L. helicina population. Samples should be taken farther off shore, along the California Current and in the Gulf of Alaska to determine the growth of L. helicina variety B as it is moved along the coast. The major part of this population is reproductive males. Two seasonal population increases, winter and spring, take place during the year.

Limacina inflata (d'Orbigny)
PLATE II

This species is most thoroughly described by Tesch (1946). Only one specimen of L. inflata was collected in the 56 tows taken between November 1959 and August 1963. The one specimen was collected in November 1961. In addition to L. helicina three other species were caught in this same tow, each being represented by only one or two individuals; Clio pyramidata, Clione limacina, and Atlanta peroni.

TABLE II

P.M.S. Tow	Date	# Specimens	Diameter (mm.)	Height (mm.)
6111	19 XI 61	1	1.5	0.9

The shell of L. inflata is very much depressed and the inner whorls do not project beyond the outer whorl when observed in side view. The resulting planorboid is depressed into the center from both sides, the larger depression being formed by the narrow, deep umbilicus. The shell of the specimen collected was, after preservation in formalin, colorless and transparent showing little or no striation or other markings. Tesch (1946) describes the opening of the shell as being more or less heart-shaped. This feature could not be observed in the specimen collected nor could it be seen in the illustration of the species given by Tesch. (Plate II.)

Neither Tesch (1946) nor McGowan (1960) state the size of the animals they collected or give a size range for the species. Measurements of Tesch's illustration show his specimen to have a diameter of 1.5 mm. and a height of .8 mm., while the specimen collected by P.M.S. has a diameter of 1.5 mm. and a height of .9 mm. The two specimens were approximately the same size. Unfortunately, their comparative size and age to other specimens is not known. A characteristic rostrum, projecting as a strengthening rib from the outer lip of adults, is mentioned by Tesch (1946). The rostrum is not well developed in the P.M.S. specimen and it might be assumed that this is a young adult of L. inflata which

has not reached maximum size.

The single specimen of L. inflata taken in the P.M.S. tows was captured at 38°14'N, 123°28'W, the westernmost area sampled by the study. L. inflata occurs in warmer oceans (Raymont, 1963) and is restricted to tropical and subtropical waters (Tesch, 1946). Locally it occurred in water 12.7°C. McGowan (1960) found its distribution in the North Pacific to be in the Equatorial and Central Water Masses and in the southerly parts of the California Current. The P.M.S. specimen was taken during the Counter Current Period and was evidently carried north of its usual range. L. inflata exists in areas of turbulence and vertical mixing and co-occurs with L. helicina in areas where the intensity of this mixing between the water masses is greatest.

L. inflata was collected in P.M.S. Tow 6111 where the assumed maximum depth of the net was 229 meters. On all of the tows taken by P.M.S., except for Station II tows taken closer to shore in shallow water, the net fished at an assumed maximum depth of 150 meters or more. These were standard oblique tows and it is expected that they sampled the entire area from the assumed maximum depth to the surface. McGowan (1960) observed that the L. inflata specimens he collected were in the upper 150 meters during the day and moved into the upper 60 meters

at night. Tesch (1946) states that specimens collected in the Atlantic were most numerous in the upper 100 meters and decreased downward. Thus, the lack of capture of specimens does not appear to be due to lack of sampling within its vertical range.

Although hundreds of specimens have sometimes been captured in a single haul (Tesch, 1946), L. inflata is obviously very rare in the P.M.S. study area. McGowan (1960) has found the greatest areas of abundance to be at the periphery of its range where there is mixing of nutrients from the Subarctic waters, but L. inflata is not usually found in coastal areas.

Both the horizontal and vertical distributions of L. inflata have been discussed above. An additional explanation of the capture of this one specimen might be in the time or seasonal distribution of the species. The specimen was caught in November, a period already shown to have a high population of L. helicina. L. inflata similarly is known to reach a population maximum during the winter or early spring in the Pacific and in the Atlantic near Bermuda (McGowan, 1960, Raymont, 1963). This specimen might indicate a seasonal maximum in the L. inflata population farther south or west, but more extensive sampling of the area would need to be done if this is to be proved.

Clio pyramidata Linne 1767
PLATE III

Clio pyramidata is the original name given this species by Linne, but it has been referred to in the literature by two synonyms, Cleodora pyramidata Massey 1932 and Euclio pyramidata Bonnavie 1913, Tesch 1946, 1948 (Tesch, 1946, 1948, McGowan, 1960). The author has chosen to use the original Clio pyramidata because of its priority and recent use in literature by McGowan (1960) and Raymont (1963). Tesch (1913) gives a complete description of this species. Tesch (1946, 1948) and McGowan (1960) give shortened but usable descriptions for species identification. Twenty specimens were caught in twelve different tows. The greatest catch in one tow was three animals.

TABLE III

P.M.S. Tow	Date	Number of Specimens	Length (mm.)	l/w ratio	#1 $1000m^3$
6003	11 III 60	1	2*	-	-
6006	2 VI 60	3	6*,3.5*,1*	-	15
6007	27 VII 60	3	7,6.5,2.5*	1.6	16
6008	19 VIII 60	1	6*	-	7
6105-19B	19 V 61	2	7*,3*	-	-
6106-6B	6 VI 61	2	2.5*	-	-
6106-18B	18 VI 61	3	4,1.5	-	-
6106-23T	23 VI 61	1	3	-	-
6111	19 XI 61	1	8	1.6	-
6112	13 XII 61	1	6	1.8	-
6204	29 IV 62	1	3	-	-
6303	19 III 63	1	1.5	-	13

*no shell present

The shell of C. pyramidata is straight and pyramidal in shape. It is not curved dorsally nor coiled similar to Limicina. There are three longitudinal ribs on the dorsal side, the mid-dorsal one being the most prominent, and a single longitudinal rib ventrally. The specimens collected in the P.M.S. tows all showed a slight curve to the right. (Plate III.) This feature is not mentioned in any of the literature examined by the author, but was found to be consistent in the specimens collected. There is no information on size in the literature examined. The specimens collected ranged from 1 mm. to 8 mm. in length. (Table III.) The shells of some of the specimens were badly broken or had been dissolved by the formalin and accurate measurements were not possible. The majority of the specimens were on the shorter end of this range and appeared to be fairly young individuals. Only a few large specimens were collected. This same situation has been reported by Tesch (1948) who found adults rare in his collections in the Indo-Pacific.

Two varieties of C. pyramidata have been described by Tesch (1946, 1948). Var. angusta is a narrow variety occurring along the northern borders of the species and var. lata a broad tropical form. McGowan (1960) did some further work on these two varieties and defines them by habitat and length/width ratio. Variety angusta occurs as

far as 50°N in waters of 27°C and has a length/width ratio of 1.0-1.4. Transitional forms between these two varieties have been found in both the Atlantic and Pacific. Young specimens of C. pyramidata all have the form of var. angusta. Var. lata is represented only in the adults. Length/width ratio measurements of the three largest P.M.S. specimens with shells are given in Table III. The smaller specimen has a length/width ratio of 1.8 which is the typical angusta form and the two larger specimens have a length/width ratio of 1.6 which is transitional between the two varieties. Consideration of the length/width ratio, the point of collection, water temperatures and size of the two larger specimens would indicate that the local adult population of C. pyramidata is a transitional form between var. angusta and var. lata.

C. pyramidata was collected in most of the tow areas except the Station II collecting area. Tesch (1948) has found C. pyramidata to be widely distributed in the Atlantic and to extend from 60°N to 40°S. In the Pacific, Danish Merchant vessels have found it up to 40°N, but there has not been extensive collecting north of this latitude. Eighteen of the twenty specimens (90%) were collected from March through August, the period of upwelling along the coast. The other two specimens were taken during the Counter Current period. This species is

a eurythermal, cosmopolitan species which exists in all except truly polar waters (Tesch, 1948). The P.M.S. specimens were caught over a wide temperature range, but were not found during periods when the temperature was below 10.1°C. (Table XII.) During both periods when C. pyramidata was taken there was mixing of the local California Current with the Eastern North Pacific Central Water. McGowan (1960) in North Pacific studies found C. pyramidata to occur in the Central Water and not in Arctic or Subarctic oceans.

C. pyramidata is most abundant in the upper 150 meters of water but has been collected to 500 meters and below. This species has the greatest vertical distribution (McGowan, 1960). The P.M.S. specimens were caught at various wire depths. The available data do not indicate any specific areas of concentration.

This is the most abundant species of the genus Clio. Comparisons of abundance with Tesch (1948) are not possible since he states abundance as 8 individuals/fishing hour. He does state that he collected as many as 400-600 individuals in a tow. McGowan (1960) did not find any specimens of C. pyramidata in the P.M.S. collection area. On the tows where flow meter readings were available, 7-16 specimens/1000m^3 were collected. (Table III.) McGowan (1960) did not find more than 1-50 specimens/1000m^3

anywhere in the North Pacific except at two isolated points: one was off southern Japan and one was on the equator off of South America. Seasonally, the two months of greatest abundance were June and July. This might be due to a summer increase in the population.

Clio balantium (Rang)
PLATE IV

This species was originally named Cleodora balantium Rang 1834, and was later referred to by two synonyms, Clio recurva Tesch 1813 and Euclio balantium Tesch 1946. Tesch (1946) gives a very adequate description for identification of this species, but McGowan's (1960) discussion should be consulted for a comparison of this species with Clio sp. (MS McGowan). Only one specimen of Clio balantium was caught during the entire P.M.S. program. This individual was caught in April 1962 along with Limacina helicina, Clio pyramidata and Clione limacina.

TABLE IV

P.M.S. tow	Date	Number of specimens	Length (mm.)	Width (mm.)
6204	29 IV 62	1	18	13

Clio balantium was the largest Euthecosome caught during the program. The shell of the one individual examined was badly broken. The tip had been broken off

and also part of the mouth. The shell is translucent, straight and broadly triangular. It is bulging in profile and has three conspicuous dorsal ribs, the median one being the broadest. Ventrally, there is only one broad rib, which occupies nearly the whole ventral surface. Tesch (1946) states that the posterior part of the shell tends to have a slight curve to the right and an obtuse embryonic shell. The curve to the right was not previously mentioned by other authors. This slight curve could be distinguished on the P.M.S. specimen. The shell has obvious waved transverse striae rising into folds. The lateral borders of the shell are double, forming a gutter-like margin along the anterior 3/4 of the shell. Upon first examination the shell had a curious appearance as if finger-like projections of the mantle were extended through it. Further study showed these to be individual hydroids attached to the shell. These hydroids, poorly preserved and in a much contracted condition, were not identified by the author. Tesch (1946, 1948) identifies a species of hydroid he found on Pacific specimens of Clio balantium as Campaniclava clionis Vanhöffen.

The P.M.S. specimen of C. balantium measured 13 mm. in width and 18 mm. in length. The length of the unbroken shell would probably have been approximately 23 mm. This

was a fairly large individual of the species, the largest being 28 mm. (McGowan, 1960) to 30 mm. (Tesch, 1948). Young specimens collected by the Dana Expeditions in the Indo-Pacific were described as having "cusped, not obtuse, embryonic shells" (Tesch, 1948). It is suspected by McGowan (1960) that these particular individuals were not C. balantium but C. teschi n. sp.

The specimen of C. balantium was taken in the west-central part of the Station I collection area. There are only ten records of the species in the Pacific, all from 35°N to 46°N or in the cooler parts of the California Current (McGowan, 1960). In the Atlantic it was found to be confined to the tropics (Tesch, 1946). The distribution of this species is not clear and there are too few records to determine its extent. The P.M.S. specimen was caught in April during the Upwelling Period. Pacific records show C. balantium to occur in the North Pacific Central Water Mass and the Transitional Region which mixes with it.

The assumed maximum depth of the net was 283 meters. This species has not been taken in deep tows and its rarity does not seem to be due to its living deep for it has been dip-netted off the surface (McGowan, 1960).

Cavolinia gibbosa (Rang)
PLATE V

The accepted name of this species is Cavolinia gibbosa. Hyalaea gibbosa (Rang), an early synonym, has fallen into disuse. The identification of the genus is by the morphological characteristics of the shell. These characteristics are variable and many of the species have forms ranging widely in appearance. Upon reviewing the available descriptions, it is the author's opinion that more information for taxonomic purposes is needed.

Only two specimens of Cavolinia gibbosa were collected in the four years of sampling. One specimen was taken in each of two tows. Both of these tows had low catches of pteropods and heteropods. In addition to Cavolinia gibbosa, one Carinaria lamarcki was found in the first catch, (P.M.S. Tow 6002), and seven Limacina helicina, three Carinaria lamarcki and two Atlanta peroni were taken in the second catch (P.M.S. Tow 6105). These were fairly unproductive tows.

TABLE V

P.M.S. Tow	Date	Number of Specimens	Length (mm.)	Width (mm.)	Thickness (mm.)
6002	21 II 60	1	9	6.7	4.9
6105-19T	19 V 61	1	animal without shell		

One of the specimens collected had a shell, the other was a large animal without a shell. The shell was hyaline with a brownish tinge. The maximum width of the shell was anterior of the lateral spines. The ventral plate of Cavolinia gibbosa characteristically forms a sharp angle projecting forward in profile view (Tesch, 1946). The ventral plate of the P.M.S. specimen did not form a sharp angle and was in shape somewhat between C. gibbosa and C. gibbosa plana, a variety described by Meisenheimer (Tesch, 1946). C. gibbosa plana is a flattened form. The plate does not project foreward. The plana variation has not been found in any one area of the species distribution and is believed by Tesch (1948) to be an individual variation and not a variation of the population. Unfortunately, records of comparative sizes were not available. The P.M.S. specimen was 9 mm. long, 6.7 mm. wide and 4.9 mm. in depth. The shell measured had no animal present in it, but a large animal was caught in the subsequent tow (P.M.S. Tow 6105-19T). From the size of the animal it appeared to be a nearly full-grown adult.

The records and distribution of this species are very patchy. C. gibbosa has been found to be comparatively rare in all areas. As in the P.M.S. study, McGowan (1960) succeeded in capturing only one or two specimens in a tow. Tesch (1948) reports taking 8-10 specimens in a single

haul. In the Indo-Pacific and tropics, C. gibbosa was rare and Tesch (1946) suspected that the species would have its maximum population abundance north of 10°N. McGowan (1960) found the greatest abundance of the species 30°N-40°N, but even there it was relatively rare. Although patchy, the distribution of C. gibbosa in the North Pacific is primarily confined to the North Pacific Central Water Mass. The two P.M.S. specimens were widely separated over the collection area. One was caught on the west and the other on the east side of the area. One specimen was caught in February and the other in May, both during the Upwelling Period. Characteristic of an epipelagic species, most of the Dana specimens of C. gibbosa were taken in the upper 150 meters of water (Tesch, 1946). Both P.M.S. specimens were taken in fairly shallow tows with an assumed maximum depth of 169-237 meters.

Corolla Dall
PLATE VI

The author was fortunate enough to have the opportunity of observing some of these animals alive and to watch them swim through the water. In the author's opinion they are by far one of the most beautiful and graceful animals to be found in the plankton. Rarely are these animals taken in an undamaged state. They are extremely fragile and are usually torn to pieces by the net. The pseudoconcha of

one specimen is illustrated here. (Plate VI.) Tesch (1946, 1948) furnishes a description of the genus but due to the rarity of undamaged specimens little is available as valid species descriptions. Nine specimens of Corolla were caught in four tows. Four individuals formed the greatest number caught in a single tow. Five pseudoconchae were found completely unattached from the animals but, presumably, belonged with the individuals caught at the same time. (Table VI.) The four remaining animals were without pseudoconchae.

TABLE VI

P.M.S. Tow	Date	Number of Specimens	Pseudoconchae	Fin Span (mm.)
5911	3 XI 59	4	4	45
6008	19 VIII 60	3	-	-
6011	28 XI 60	1	1	-
6201	17 I 62	1	-	5*

*specimen small-questionable identification

When observed alive Corolla looks like a transparent butterfly swimming through the water. The swimming action of the fins resembles that of the fins of a ray. The fins show the distinct intercrossing muscular fibers. The proboscis is well developed and there is a dark pigmented ring around the aboral pole of the nucleus. There is no shell in this family but a cartilaginous pseudoconcha.

The animal is attached to the pseudoconcha by an oval swimming plate. The plate is taxonomically important in the identification of the species (Tesch, 1946) and is damaged when the animal is torn away from the pseudoconcha, as is usual in most collections. When in sea water, the pseudoconchae are almost transparent and can not be seen. They have a refractive index almost that of water. The pseudoconcha is flattened, purselike in shape, with the opening about half-way down the length of the concha, and covered on the surface with scattered knobs.

Four larger individuals were collected in P.M.S. Tow 5911. The pseudoconchae were approximately the same size (35 mm.). The individual animal showing the least amount of damage was measured and has a fin span of 45 mm. The one individual taken in P.M.S. Tow 6201 was extremely small and a positive identification was not possible.

Too few specimens of this genus have been caught and identified to give any conclusive data on their distribution. Tesch (1946) states they are found everywhere in the tropical Atlantic. Locally, Corolla was found in January, August and November during both the Counter Current and Upwelling Periods. This genus appears to be epipelagic. The two largest yielding tows were fishing at about 250 meters or less. The author was able to catch some specimens of this genus in the Tropical

Pacific during the summer of 1963 and they were taken at 200 meters or less.

Clione limacina (Phipps 1774)

This species has no shell and is very contractile. The individual form of the animal varies greatly depending upon preservation and contraction. It would be ideal to be able to obtain these animals while alive and anaesthetize them before preservation. Diagrams of C. limacina illustrating morphological characteristics are given by Tesch (1950) and good anatomical diagrams are presented by Morton (1958). Several authors have previously intensively studied and described C. limacina. For this and synonyms refer to Tesch (1950). This was the second most abundant species to be collected. A total of 44 specimens were taken at 19 stations. They ranged from 1-8 individuals per tow with most of the tows producing 1 or 2 specimens.

TABLE VII

P.M.S. Tow	Date	Number of Specimens	Length (mm.)
6005	10 V 60	1	9
6009	17 IX 60	1	3**
6102-2	2 II 61	2	6,3*
6102-25B	25 II 61	2	--
6104B	27 IV 61	1	7
6105-7T	7 V 61	4	10,9*,9,6**
6105-19T	19 V 61	3	8*,7,7
6105-19B	19 V 61	2	4*,4
6105-23T	23 V 61	4	10,10,5,2*
6105-23B	23 V 61	8	12,11,10,10,9*,8,7**,6*
6105-30T	30 V 61	1	2*
6105-30B	30 V 61	5	11,5,4
6106-6B	6 VI 61	1	9
6106-18B	18 VI 61	3	7,7,6
6106-23-2	23 VI 61	1	3
6111	19 XI 61	2	4,3
6201	17 I 62	1	8
6204	29 IV 62	1	9
6301	13 I 63	1	5*

*length of specimen greatly contracted.
**posterior ciliated larval ring present.

C. limacina has a distinct head and acuminate posterior end. There are three pairs of cephalochones and one pair of hook sacs in the buccal region. In the mature individuals there are about fifteen hooks in each sac (Morton, 1958). These hooks are chitinous with a slight curvature. There are no external gills and the posterior footlobe is reduced. The wings, rounded flaps attached at the midline, are modifications of the foot. For a description of the swimming of the animal and action of these wings see Morton (1958).

The P.M.S. specimens of C. limacina ranged in size from 3-12 mm. Three of the specimens showed evidence of still having a posterior ciliated ring which is characteristic of the larval stages. Lebour (1931) studied C. limacina around Plymouth. She found them to be sexually mature at 4-5 mm. while still having some of the larval characteristics. The largest specimens she recorded were 12 mm. These were comparable to the size of the specimens found in the P.M.S. study. These are shorter than the true Arctic form which reaches 40-41 mm. in length. Morton (1958) observed sexual development in specimens as small as 2.5 mm.

Specimens of C. limacina were taken over the entire P.M.S. collection area. These were caught throughout the year during all current periods along the coast and through the entire temperature range of the area. C. limacina characteristically occurs in the Arctic-boreal waters in the Atlantic and North Pacific (Lebour, 1931; Tesch 1950). Locally, Subarctic water is mixing in the Transition Region and is present all year as the species indicates. Other planktonic species characteristically found in Arctic and Subarctic waters, (Okiopleura labradorensis, Limacina helicina, etc.), are also commonly found in the area most of the year.

Little is known about the vertical distribution of C. limacina. It was taken in some P.M.S. tows in which the assumed maximum depth was as little as 48-150 meters. The least depth was in the shallow water of the Station II area. It seems evident that the species is epiplanktonic.

Most of the specimens caught were taken in June 1961. This is partially due to the increased intensity of sampling during this period, but the number of specimens per haul was also greater at this time. Although Raymont (1963) reports this species as having little seasonal change during the year, Lebour (1931) and Morton (1958) both state that they have observed a summer abundance in this species and that it breeds around Plymouth in June. Lebour (1931) states that C. limacina usually occurs with and feeds upon Limacina retroversa in the Atlantic. Locally, C. limacina occurred with the closely related species Limacina helicina which it may be using as food. The P.M.S. specimens were examined but were too poorly preserved to identify stomach contents.

Atlanta peroni Lesueur 1817

The author has identified the P.M.S. specimens as A. peroni but they may be a closely related species, A. gaudichaudi Souleyet 1852. The species descriptions consulted were by Tesch (1949). These two forms are

considered to be valid species but it is almost impossible to separate them. A total of 24 specimens were collected at 11 stations. There were one to four specimens at each of the eleven stations. All of the specimens were caught in the winter or early spring.

TABLE VIII

P.M.S. Tow	Date	Number of Specimens	Diameter (mm.)
5911	3 XI 59	4	2.5,2.0,1.7,0.7
5912	21 XII 59	3	1.0,0.9
6003	11 III 60	1	1.5
6105-19T	19 V 60	2	2.5,2.2
6105-30T	30 V 61	1	2.2
6105-30B	30 V 61	2	3.1
6111	19 XI 61	1	1.1
6201	17 I 62	3	2.1,1.7,1.4
6203	8 III 62	2	2.2
6301	13 I 63	4	1.9,1.1,1.1,1.0
6303	19 III 63	1	0.6

In most of the specimens the shell had been completely broken away or dissolved. Only in half of the specimens was the shell found to be intact and then the keel was usually broken away. The shell is flattened and has four (A. gaudichaudi) or four and one-half to five (A. peroni) whorls. The base of the keel is sometimes a diffuse brown (A. peroni) or buff or reddish brown (A. gaudichaudi). As in A. lesueuri the keel penetrates between the penultimate and the last whorl in the mature specimens. This could be observed in the P.M.S. specimens 2.2 mm. in diameter or

larger. The characteristic heteropod eyes are evident. In A. peroni the anterior part of the eye is a clear amber color distinct from A. lesueuri where this part of the eye is colorless. It was not possible to compare live specimens and this characteristic may be an artifact of preservation. In A. peroni the mouth of the shell is smaller (40% of the diameter of the animal) than in A. gaudichaudi (nearly one-half or 50%). In such small and broken specimens, especially when the young of both resemble A. gaudichaudi, this characteristic is not reliable for identification. A. peroni is the largest species of Atlanta and reaches a size of 10-11 mm. The P.M.S. specimens ranged from 0.6-3.1 mm. These are young specimens. It is possible that the Pacific form may not reach the large size of the Atlantic form. The larger P.M.S. specimens (1.7 mm. and larger) showed development of the spermatophore indicating sexually mature males.

A. peroni specimens were collected over the entire Station I area. All of the collections were in the winter, November to January, during the Counter Current Period or in the early spring, March to May, during a period of upwelling along the coast. Collecting by Tesch (1949) in the Atlantic showed A. peroni to avoid the equatorial waters. It was also found to be present in

the Indo-Pacific. Locally, it is found to be present during the parts of the year when there is great mixing of the California Current with the Eastern North Pacific Central Water. The species is present in the upper layers of the water down to a few hundred feet and was caught in both top and bottom tows taken at the same stations (6105-30T, 6105-30B). There does not appear to be a great difference in the abundance of A. peroni between the winter and spring collections. Sexually mature males with spermatophores were found during both seasons.

Atlanta lesueuri Souleyet 1852

Identification of this species is difficult due to the breaking and poor preservation of the very fragile shell. Tesch (1949) furnished a description of Atlanta lesueuri, but if the specimens are in poor condition further sources of identification are needed. Dr. John McGowan (1963) graciously confirmed the author's identification of this species. Tesch (1906) calls this species Atlanta oligogyra. Eleven specimens were collected in two different P.M.S. tows. One specimen was collected in a single tow and ten were collected in a subsequent tow about two years later. No other pteropods or heteropods were found in the tows with A. lesueuri except Limacina helicina.

TABLE IX

P.M.S. Tow	Date	Number of Specimens	Diameter (mm.)
6012	28 XII 60	1	-
6302	24 II 63	10	0.6
			0.6
			0.5
			0.5
			0.5
			0.5
			0.4
			0.4

The shell of A. lesueuri is very much flattened and shows no obvious sculpture. These shells are very fragile and diagnostic features of the shell such as the keel are easily broken or quickly dissolved by formalin. The shell has a high encircling keel which penetrates between the penultimate and the last whorl. Only three whorls are present (Tesch, 1949) but they are sometimes difficult to distinguish. The inner whorls are slightly lavender in color, unlike the other species encountered. The eyes are very black and noticeable in these specimens as they are in most heteropods. All of the specimens collected were small and of a fairly uniform size. They ranged from 0.4-0.6 mm. in diameter, the largest number falling in the middle of this range.

The two P.M.S. tows which collected A. lesueuri were widely separated within the Station I collecting area. The first specimen was taken on the west side of the area

and the other ten specimens were taken on the east side. They were all collected during the Counter Current Period when the water was flowing north along the coast. The temperature at both times of collection was 12.5°C. This species is probably distributed in the Eastern North Pacific Central Water Mass and was brought into the Transitional Region as a result of mixing currents. There is little data or evidence for the distribution of A. lesueuri in the North Pacific. The majority of the records are for the Atlantic and some in the Indo-Pacific. A. lesueuri occurs in the surface layers of the water. The net reached an assumed maximum depth of 110-141 meters when they were collected. Other deeper tows did not produce any specimens.

Little can be concluded on the abundance of this species except that in P.M.S. Tow 6302 the ten specimens give an abundance of 136 individuals per 1000m^3. It is surprising that with this large number collected in one tow that none were found in other tows. It would appear that their distribution is very patchy.

Carinaria lamarcki Peron et Lesueuri 1810
PLATE VII

This species has appeared in the literature under a wide number of synonyms, C. fragilis Bory de Saint-Vincent 1804, C. mediterranea Blainville 1825, C. cymbium Guerin

1829-44, Cuvier 1830, C. australis Quoy et Gaimard 1832, C. punctata d'Orbigny 1836, C. grimaldi and C. pseudorugosa Vayssiere 1904 (Tesch, 1949) and C. japonica Okertani (McGowan, 1963, personal communication). Some of these synonyms are merely Pacific forms of C. lamarcki. Tesch (1949) describes this species in the Dana Report on Heteropoda. With the aid of this description and personal communication with Dr. John McGowan at Scripps Institute of Oceanography, the author was able to identify the P.M.S. specimens. Only three specimens of C. lamarcki were collected, one at each of three stations. Two of the specimens were collected in consecutive months and the third was caught nearly two and one-half years later.

TABLE X

P.M.S. Tow	Date	Number of Specimens	Length (mm.)
6002	21 II 60	1	25
6003	11 III 60	1	18
6208	24 VIII 62	1	23

The shell of C. lamarcki is flattened and depressed, the length at the base being about 165% of the greatest height. In the other species the length at the base is distinctly less than the greatest height. The thick cutis on the trunk and, to a minor degree on the probosis, is studded with obtuse tubercles (Tesch, 1949), but these

were not very obvious on the young P.M.S. specimens. The three specimens ranged in size from 18-25 mm. These are comparatively small individuals of C. lamarcki, which reaches 220 mm. in the Mediterranean.

The three points of collection were dispersed over the Station I area. All three of the collections were made during the Counter Current Period when there was a large amount of mixing with the Eastern North Pacific Central Water. C. lamarcki occurs in the surface layers and was taken in tows when the assumed maximum depth was 169-283 meters. Many tows fished deeper but specimens were not collected. Lo Bianco, as cited by Tesch (1949), states that C. lamarcki is characteristic in the exactness of its date of appearance in the Mediterranean. It is first captured in the month of February and from then until May, after which it disappears, to be caught again only in September and October. This is interesting considering the North Pacific specimens were caught in February, March and the last week of August. When first examined, one C. lamarcki had a small chaetognath half way into its probosis. At first the author assumed that this may have been due to crowding in the tow and/or a reaction to the formalin, but it is now suspected that the chaetognath was being used as food. Raymont (1963) has found Carinaria to feed partially on copepods but to a large extent on

chaetognaths.

Carinaria cristata (Linne)
PLATE VIII

Two early synonyms, Patella cristata Linne (1766) and Carinaria vitrea Lamarck 1801, were used for this species. Tesch (1949) refers to it as Carinaria cristata and furnishes an excellent description. Only one specimen of C. cristata was collected during the entire period of sampling. This was in October 1962. The one specimen of C. cristata and two specimens of Limacina helicina were the only molluscs in the tow.

TABLE XI

P.M.S. Tow	Date	Number of Specimens	Length (mm.)
6210	24 X 62	1	55

The P.M.S. specimen of C. cristata was brought into the laboratory a few hours after being caught and was preserved in formalin. At that time the entire body of the animal was tinged a delicate shade of pink. The shell was a slightly deeper shade of pink. This was one of the most beautiful animals encountered in any of the tows examined. The shell of this species is much more elevated than that of C. lamarcki. The posterior edge of the shell is straight, not concave as described by Tesch

(1949), for the adults of C. cristata. The keel of the shell is narrow and the plications are directed downwards. The shell is very fragile and the keel is very easily broken. Small obtuse tubercles line the ventral side of the tail posteriorly and the dorsal side of the tail just posterior of the shell. Tesch (1949) describes a characteristic crest rising immediately behind the stalk of the visceral nucleus and continuing up to the tip of the tail.

C. cristata is the largest representative of all heteropods. One specimen figured by Tesch (1949) measured 460 mm., young specimens measuring 25-30 mm. Pacific forms may not attain such large sizes; the P.M.S. specimen is 55 mm. This specimen is possibly a young individual as indicated by its size and the straightness of the posterior edge of the shell.

C. cristata was collected at 38°12'N, 123°27'W, the farthest point south collected by a P.M.S. tow. This collection was in October. The temperature was 13.9°C corresponding to the usual higher temperatures for the period. The majority of the records for the collection of this species are in the Indo-Pacific. There is one record of it being collected in the North Pacific by a Danish ship at 39°30'N, 166°50'W (Tesch, 1949), a point northwest of the P.M.S. collecting area. Both of these

records for C. cristata in the North Pacific lie in line with the northern periphery of the Eastern North Pacific Central Water Mass. The P.M.S. specimen was caught to the east in the Transition Region.

The P.M.S. specimen of C. cristata was taken when the maximum depth of the net was between 135 and 153 meters. This corresponds with the information given by Tesch (1949) who says the species lives in the upper layers of water. At present little can be said about the distribution or abundance of this species with the information available.

DISCUSSION

The pelagic gastropods, collected over a four-year period, near Dillon Beach were studied. A total of 1,747 specimens was collected in fifty-six tows. No new species or new variations of species were found. Eleven species were collected and identified. These eleven species were either pteropods or heteropods. No pelagic nudibranchs or other pelagic gastropods were collected.

The populations of two species in the area were composed of varieties of these species. The Limacina helicina population was of variety B specimens as described by McGowan (1960). These are derived from a parent population which exists in the Subarctic waters off shore to the north. The Clio pyramidata population sampled was a transition form between the warm water var. lata and the colder water var. angusta. It is the author's belief that the genus Cavolinia needs more taxonomic work and with further study some of the present species will be reduced to varieties or forms.

There is little size information available on the species studied especially for the North Pacific area. Records have been made of some of the largest specimens found. There are no accounts of average population size or growth or seasonal variations. Large specimens of both Clio balantium and Cavolinia gibbosa were caught.

TABLE XII. Station Data and Number of Individuals per Tow.

P.M.S. Tow	Date	Latitude	Longitude	Surface Temperature	Depth of Sea (m.)	Assumed Max. Depth (m.)	Duration of Tow	Volume filtered 1000m^3	Limacina helicina	Limacina inflata	Clio pyramidata	Clio balantium	Cavolinia gibbosa	Corolla	Clione limacina	Atlanta peroni	Atlanta lesueuri	Carinaria Tamarckii	Carinaria cristata	Total
5911	3 XI 59	38°19'	123°28'	12.1	225	175	29	-	4					4		4				12
5912	21 XII 59	38°14'	123°23'	12.5	535	170	41	-	1							3				4
6002	21 II 60	38°13'	123°23.5'	10.5	214	169	37	-	-				1					1		2
6003	11 III 60	38°15'	123°27.5'	10.8	535	283	35	-	34		1					1		1		37
6004	5 IV 60	38°14.5'	123°26.5'	11.1	220	189	40	-	41											41
6005	10 V 60	38°14'	123°26'	12.1	249	198	25	112	111						1					112
6006	2 VI 60	38°14'	123°27.5'	11.4	535	283	35	197	6		3									9
6007	25 VII 60	38°14.5'	123°25'	10.1	228	219	42	138	23		3									26
6008	19 VIII 60	38°12.5'	123°25'	11.4	274	198	27	138			1			3						4
6009	17 IX 60	38°13'	123°25'	11.2	310	283	40	196	14						1					15
6010	15 X 60	38°14'	123°26'	12.9	284	270	21	142	1											1
6011	28 XI 60	38°14'	123°27'	12.4	535	424	38	216	275					1						276
6012	28 XII 60	38°15'	123°28'	12.5	366	389	30	163	61								1			62
6102-2	2 II 61	38°15'	123°28'	12.9	330	235	33	147	17						2					19
6102-25T	25 II 61	38°14'	123°27'	11.9	402	127	-	-												-
6102-25B	25 II 61	38°14'	123°27'	11.9	402	254	40	315	1						2					3
6103B	29 III 61	38°13'	123°27'	12.4	410	321	35	241	8											8
6104T	27 IV 61	38°14'	123°27'	11.3	530	193	18	-	1											1
6104B	27 IV 61	38°14'	123°27'	11.3	530	386	38	379	11						1					12
6105-7T	7 V 61	38°13'	123°29'	11.1	440	193	22	-	12						4					16
6105-7B	7 V 61	38°13'	123°29'	11.1	440	386	48	-	26											26
6105-7#2	7 V 61	38°16'	123°10'	9.0	91	64	8	-	2											2
6105-19T	19 V 61	38°14'	123°28'	-	-	212	25	-	7				1		3	2				13
6105-19B	19 V 61	38°14'	123°28'	-	-	424	43	-	21		2				2					25
6105-19#2	19 V 61	38°17'	123°12'	8.9	-	57	14	-	35											35
6105-23T	23 V 61	38°14'	123°28'	11.7	535	193	22	-	20						4					24
6105-23B	23 V 61	38°14'	123°28'	11.7	535	386	41	-	21						8					29
6105-30T	30 V 61	38°14'	123°28'	13.3	535	150	26	-	27						1	1				29
6105-30B	30 V 61	38°14'	123°28'	13.3	535	300	48	-	146						5	2				153
6106-6B	6 VI 61	38°14'	123°28'	14.4	535	424	40	-	8		2				1					11
6106-6#2	6 VI 61	38°16'	123°12'	12.5	91	71	8	-	11											11
6106-18T	18 VI 61	38°14'	123°28'	13.9	535	212	27	-	4											4
6106-18B	18 VI 61	38°14'	123°28'	13.9	535	424	43	-	18		3				3					24
6106-23T	23 VI 61	38°14'	123°28'	11.4	535	212	23	-	1		1									2
6106-23B	23 VI 61	38°14'	123°28'	11.4	535	424	44	-	5											5
6106-23#2	23 VI 61	38°16'	123°12'	8.5	91	70	11	-	31						1					32
6107	18 VII 61	38°14'	123°28'	9.9	535	344	10	-	12											12
6108	12 VIII 61	38°14'	123°28'	13.1	-	424	35	-	11											11
6109	15 IX 61	38°14'	123°28'	12.6	-	424	29	-	4											4
6111	19 XI 61	38°14'	123°28'	12.7	535	229	23	-	71	1	1				2	1				76
6112	13 XII 61	38°13.5'	123°28'	11.2	535	212	15	-	5		1									6
6201	17 I 62	38°15.5'	123°24.5'	11.1	202	163	22	-	26					1	1	3				31
6203	8 III 62	38°14'	123°28'	11.5	535	212	42	-	154							2				156
6204	29 IV 62	38°14'	123°27'	11.1	535	283	25	-	112		1	1			1					115
6206	12 VI 62	38°13'	123°27'	9.7	535	150	50	-	39											39
6207	26 VII 62	38°13'	123°27.5'	11.1	535	150	37	-	25											25
6208	24 VIII 62	38°13'	123°26.5'	12.9	535	212	24	-	62									1		63
6209	23 IX 62	38°12'	123°27'	-	535	177	23	-	9											9
6210	24 X 62	38°12'	123°27'	13.9	535	153	15	94	2										1	3
6212	21 XII 62	38°14'	123°17'	12.0	535	141	13	79	10											10
6301	13 I 63	38°14'	123°17'	11.6	535	115	11	74	31						1	4				36
6302	24 II 63	38°14'	123°17'	12.5	535	141	8	73	15								10			25
6303	19 III 63	38°14'	123°17'	11.1	535	141	12	77	7		1					1				9
6306	14 VI 63	38°14'	123°17'	11.9	535	141	12	58	4											4
6307	13 VII 63	38°14'	123°27'	12.3	535	129	16	71	25											25
6308	7 VIII 63	38°14'	123°27'	-	535	173	27	48	3											3
Total									1631	1	20	1	2	9	44	24	11	3	1	1747

There were only one or two specimens of each species and all were taken in the spring and summer during the Upwelling Period. All of the other species were composed of populations made up of small or medium size specimens. The mean size of the Limicina helicina population was 1.1 mm. The ovitestis of L. helicina was stained with acid carmine and the reproductive stages were examined. The majority of the population was found to be reproductive males.

Two Arctic and Subarctic species, Limacina helicina and Clione limacina were caught at the Station I and Station II collection areas during the entire year. It is probable that Clione limacina was feeding on Limacina helicina. These two Subarctic species totaled 1,675 individuals. They were the two most abundant species taken during the study. Two species of Subarctic chaetognaths were also reported from the same tows (Renshaw, 1963). Sagitta maxima and Eukrohnia hamata were caught through most of the year in 1960. Fager and McGowan (1963) in a study of species groups in the North Pacific show Limacina helicina to characterize the Subarctic Water Mass along with several other species, two of which, Thysanoessa longipes and Euphausia pacifica, are quite common locally in all the tows. Subarctic species of molluscs, chaetognaths, and euphausids are

present and abundant in the Dillon Beach area over the entire year. This corresponds with hydrographic data and shows dominance of Subarctic water in the area. None of the other nine species of pelagic gastropods studied in this report were present during the entire year nor were they taken at the Station II collecting area.

On a basis of their occurrence the remaining nine species of pelagic gastropods were divided into two groups. The first group was the most abundant of the two and occurred during the Upwelling and Counter Current Periods. This group was characterized by fairly cosmopolitan species which occur in the Equatorial and Central Water Masses. Four species, Clio pyramidata, Corolla sp., Atlanta peroni, and Atlanta lesueuri comprise the group and total 65 individuals. This group was second in abundance to the two Subarctic species mentioned above. Clio pyramidata and Atlanta peroni are also shown by Fager and McGowan (1963) to occur in the Central Water Mass although they are not always associated together. Renshaw (1963) found Sagitta decipiens, Sagitta bierii, and Sagitta minima to have the same general distribution.

The second group is composed of five species, Limacina inflata, Clio balantium, Cavilinia gibbosa, Carinaria lamarcki, and Carinaria cristata, totaling

only 8 individuals. These are tropical or warm water species and only one to three specimens of each species were taken. Their distribution in the local area is patchy and rare and they were caught mainly during the Counter Current Period. Sagitta hexaptera, Sagitta enflata and Krohnitta sublilis were listed by Renshaw (1963) as locally occurring tropical species of chaetognaths. Three of the mentioned species, Limacina inflata, Sagitta hexaptera and Krohnitta subtlilis were shown by Fager and McGowan (1963) to be species which are associated together in more than half of the tows they studied. Thus the pelagic gastropods, Chaetognaths studied by Renshaw (1963) and recurrent zooplankton groups studied by Fager and McGowan (1963) indicate the Dillon Beach area is dominated by Subarctic water which mixes with the North Pacific central water. An increase in the number of species results during the periods of greatest mixing.

Although opening and closing nets were not used, the species all appear to be epipelagic. All of the species were present in shallower tows and no species was present in only the deeper tows. A flow meter was attached to the plankton net during some of the P.M.S. tows and the volume of water filtered in cubic meters was recorded.

When this information was available, the abundance of the animals could be expressed in number of specimens/1000m^3. Both winter and early spring population increases were indicated from the data available. The figures on population abundance obtained in this study were comparable to figures presented by McGowan (1960) who also expressed population abundance in number of specimens/1000m^3. This method appears advantageous as it was not possible to compare population abundance figures with Tesch (1946, 1948) who expressed it in number of specimens/fishing hour.

Further work on this group of animals needs to be done and should prove profitable to our understanding of the oceans. Taxonomically the pelagic gastropods have been extensively studied, though some areas need a study to straighten out the synonyms. Little or no extensive work has been done on this group in the fields of distribution, life cycles, growth rates, reproduction, physiology and behavior especially in the North Pacific. Future studies will require better methods of preservation considering the special requirements of the group. They will also require a method of reporting data which allows comparison of results.

SUMMARY

1. A study of the pelagic gastropods collected over a four-year period off shore west of Dillon Beach was conducted.
2. Fifty-six plankton tows were taken at the head of Bodega Submarine Canyon, located twenty-five miles off shore. The collection area was situated in the California Current System.
3. Eleven species of pteropods and heteropods were identified. These eleven species compose the entire pelagic gastropod population of the area as represented in the samples. There were six species of thecosomes, one species of gymnosomes and four species of heteropods.
4. The specimens were measured and their size, distribution and population changes are discussed.
5. Tissue of the ovitestis of Limacina helicina was stained with acid carmine and the reproductive stages examined.
6. Two species present in Subarctic waters, Limacina helicina and Clione limacina, were present throughout the year. The other nine species occur in the Eastern North Pacific Central Water and were present during the Upwelling and Counter Current Periods.
7. Limited work has been completed in the field and extensive studies remain to be done on the pelagic gastropods of the North Pacific.

8. The specimens taken were all preserved in formaldehyde at the time of collection. Many of the shells were dissolved as a result of this preservation.
9. Limited work has been completed in the field and extensive studies remain to be done on the pelagic gastropods of the North Pacific.

BIBLIOGRAPHY

Fager, E. W., and J. A. McGowan

1963. Zooplankton Species Groups in the North Pacific. Science, 140:453-460.

Fretter, V., and A. Graham

1962. British Prosobranch Molluscs. Ray Society, London. 755 pp.

Hsiao, S. T. C.

1939a. The reproductive system and spermatogenesis of Limacina (Spiratella) retroversa (Flem.). Biol. Bull. Woods Hole, 76(1):7-25.

1939b. The reproduction of Limacina retroversa (Flem.) Biol. Bull. Woods Hole, 76:280-303.

Lebour, M. V.

1931. Clione limacina in Plymouth waters. Jour. Mar. Biol. Ass. U. K., 17:785-796.

McGowan, J. A.

1960. The systematics, distribution, and abundance of the Euthecosomata of the North Pacific. Dissertation University of Calif., Scripps Institute of Oceanography. 212 pp.

1963. Geographical variation in Limacina helicina in the North Pacific. Systematics Ass. Pub. #5, 109-128.

Morton, J. E.

1954. The pelagic mollusca of the Benguela Current. Discovery Rept. 27:163-200.

1954. The biology of Limacina retroversa. Jour. Mar. Biol. Ass. U. K., 33(2):297-312.

1954. Observations on the gymnosomatous pteropod Clione limacina (Phipps). Jour. Mar. Biol. Ass. U. K., 37(2):287-297.

1958. Molluscs. Hutchinson Univ. Lib. London, 232 pp.

Pruvot-Fol, A.

1954. Opisthobranchia. La Faune de France. Paris.

Raymont, J. E. G.

1963. Plankton and Productivity in the Oceans. The McMillan Co., New York. 660 pp.

Redfield, A. C.

1939. The history of a population of Limacina retroversa during its drift across the Gulf of Maine. Biol. Bull., 76(1):26-47.

Renshaw, R. W.

1962. The chaetognaths of the Dillon Beach Area and their possible use as indicators of water movements. M.A. Thesis, Univ. of the Pacific. 71 pp.

Schwartzlose, R. A.

1962. Nearshore currents of the Western United States and Baja California as measured by drift bottles. C.C.O.F.I. 9:15-22.

Skogsberg, T.

1936. Hydrography of Monterey Bay, California. Thermal conditions, 1929-1933. Trans. of the Amer. Phil. Soc., 29:1-152.

Sverdrup, H. U., M. W. Johnson, and R. H. Fleming.

1946. The Oceans, their physics, chemistry, and general biology. Prentice Hall, New York. 1087 pp.

Tesch, J. J.

1913. Pteropoda, Mollusca. Das Tierreich, 36, Lieferung, 154 pp.

1946. The thecosomatous pteropods. I. The Atlantic. Dana Rept. no. 28, pp. 1-82, 8 pls.

1948. The thecosomatous pteropods. II. The Indo-Pacific. Dana Rept. no. 30, pp. 1-44, 3 pls.

1949. Heteropoda. Dana Rept. no. 34, pp. 1-53, 5 pls.

1950. The Gymnosomata. II. Dana Rept. no. 36.

EXPLANATION OF PLATES

PLATE I — *Limacina helicina*

a. From opening of shell.

b. From above.

c. From beneath.

d. From opening, showing internal spires.

PLATE II — *Limacina inflata* [a, b, c after Tesch (1946)]

a. From opening of shell.

b. From above.

c. From below.

d. From opening of shell.

e. From above.

f. From below.

PLATE III — *Clio pyramidata* (dorsal view)

PLATE IV — *Clio balantium*

a. Dorsal view.

b. Lateral view.

PLATE V — *Cavolinia gibbosa*

a. Dorsal view.

b. Ventral view.

c. Lateral view.

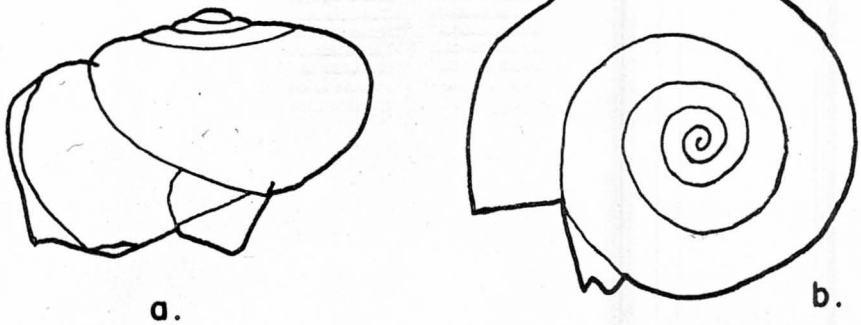
PLATE VI — *Corolla*

Pseudoconcha

PLATE VII — *Carinaria lamarcki*

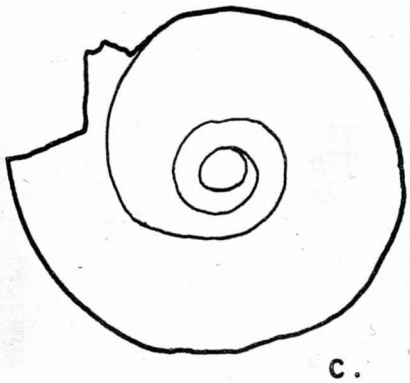
PLATE VIII — *Carinaria cristata*

PLATE I



a.

b.



c.

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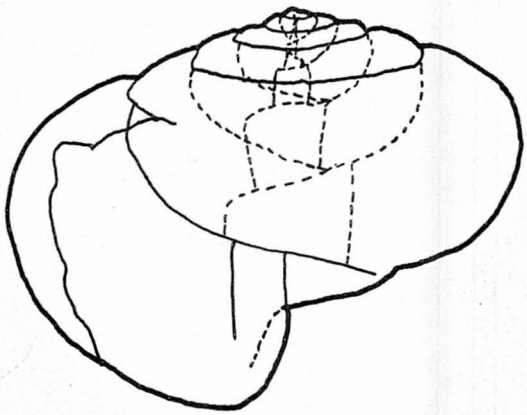

d.

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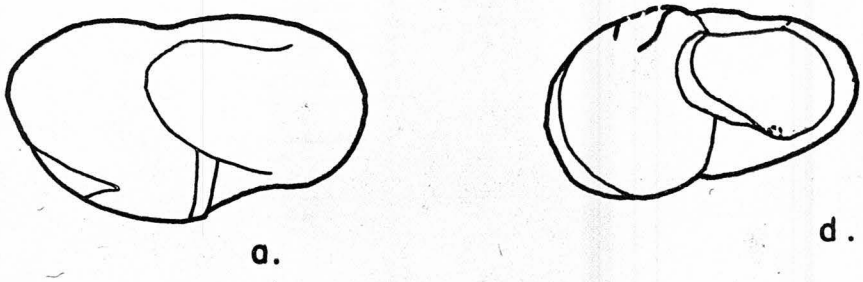

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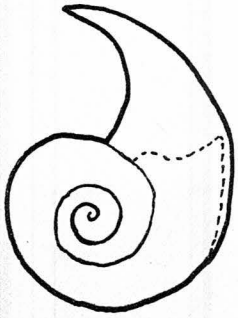
d.

b.



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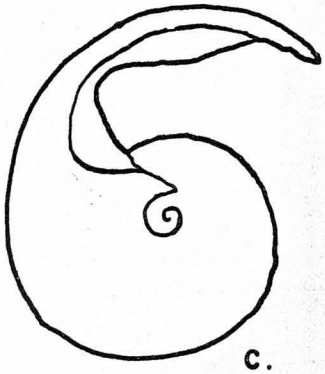

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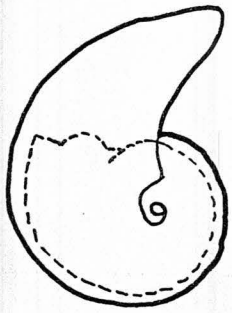
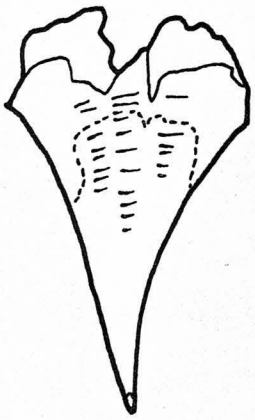


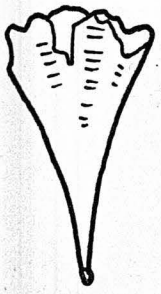
f.

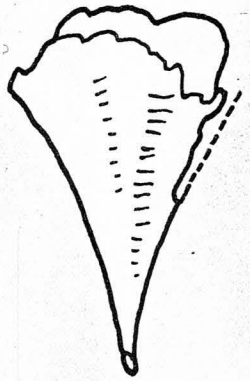
1 mm.

1 mm.

PLATE III







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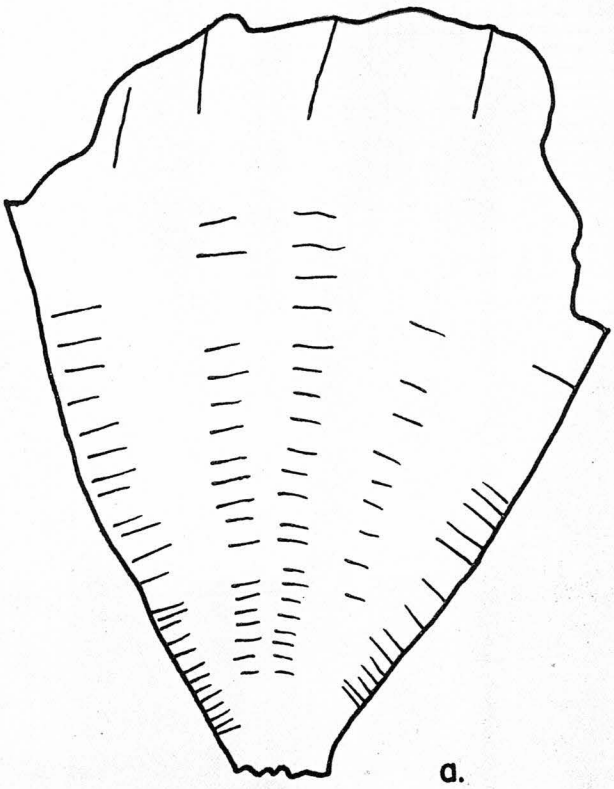

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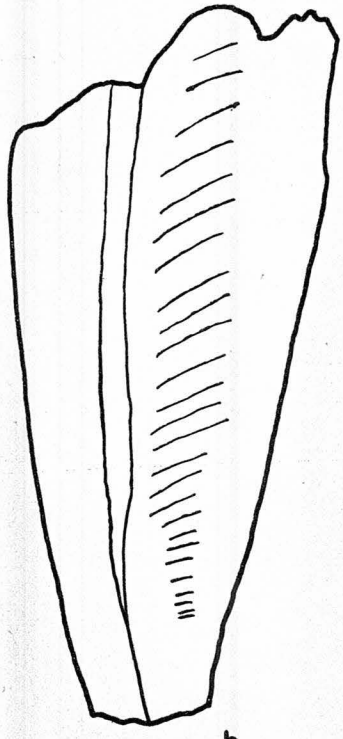

b.

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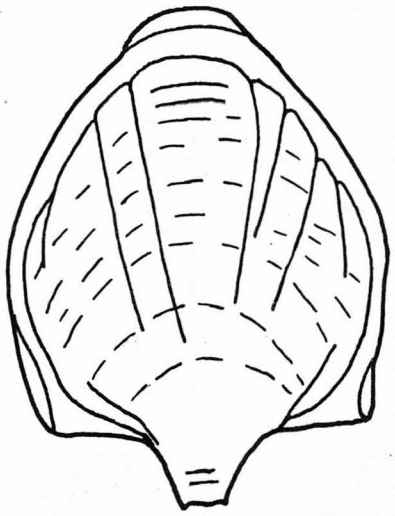
PLATE V



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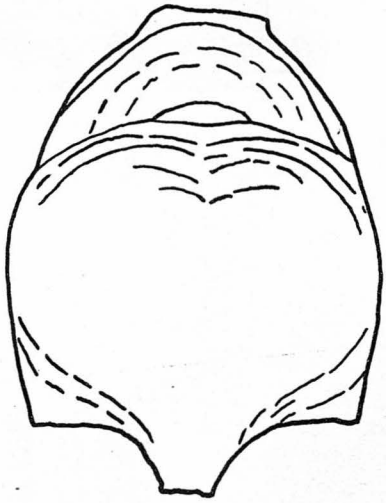

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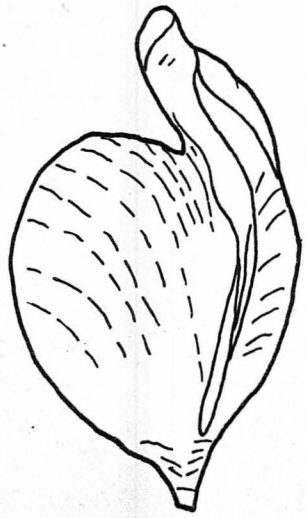

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PLATE VI

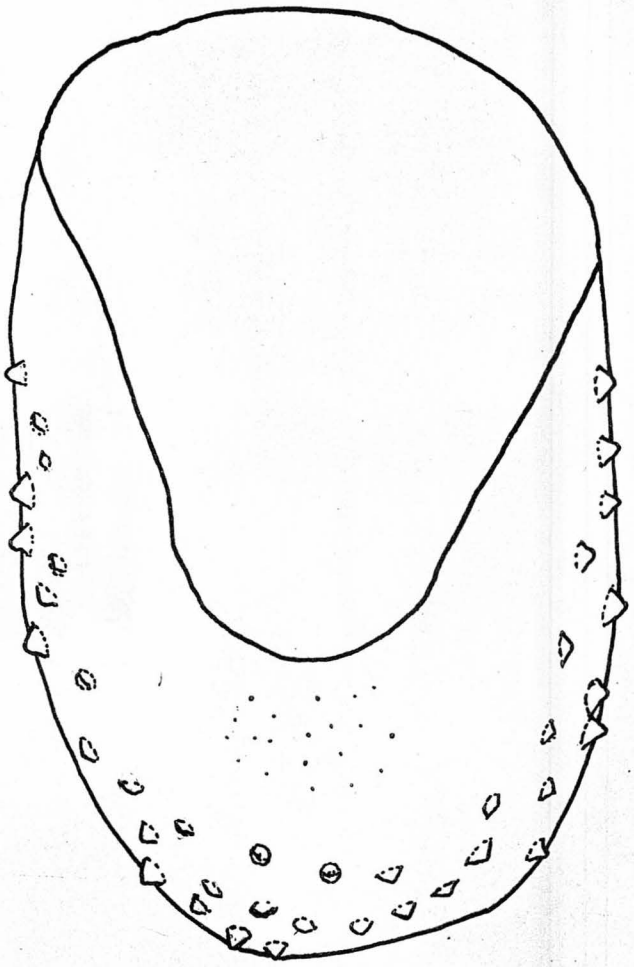

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PLATE VII

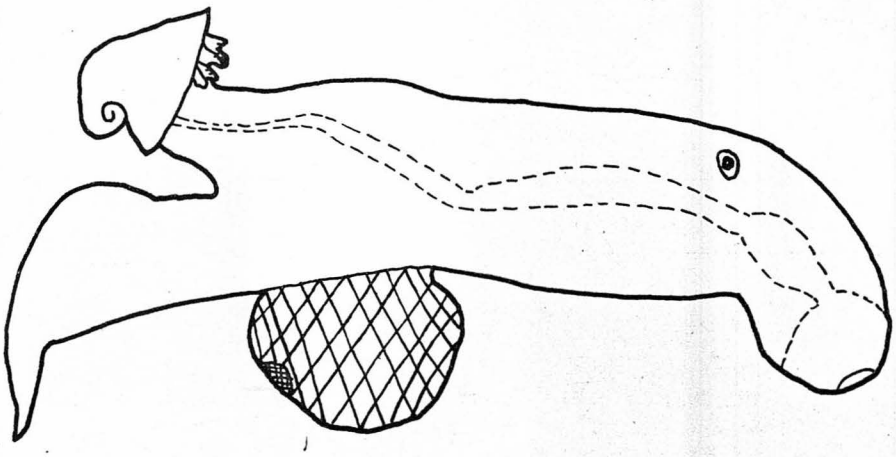

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PLATE VIII